US007233854B2

(12) United States Patent
Rayl et al.

(10) Patent No.: **US 7,233,854 B2**

(45) Date of Patent: **Jun. 19, 2007**

(54) **METHOD FOR IMPROVING FUEL ECONOMY AND PERFORMANCE WHEN DEACTIVATING CYLINDERS WITH VEHICLE CRUISE CONTROL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 283 days.

(21) Appl. No.: **10/939,548**

(22) Filed: **Sep. 13, 2004**

(65) **Prior Publication Data**

US 2006/0058939 A1 Mar. 16, 2006

(51) **Int. Cl.**

B60K 31/00 (2006.01)

G06F 7/00 (2006.01)

(52) **U.S. Cl.** **701/93**; 701/85; 180/170; 123/352

(58) **Field of Classification Search** 701/79, 701/93, 85; 123/352, 376; 340/441; 180/170

See application file for complete search history.

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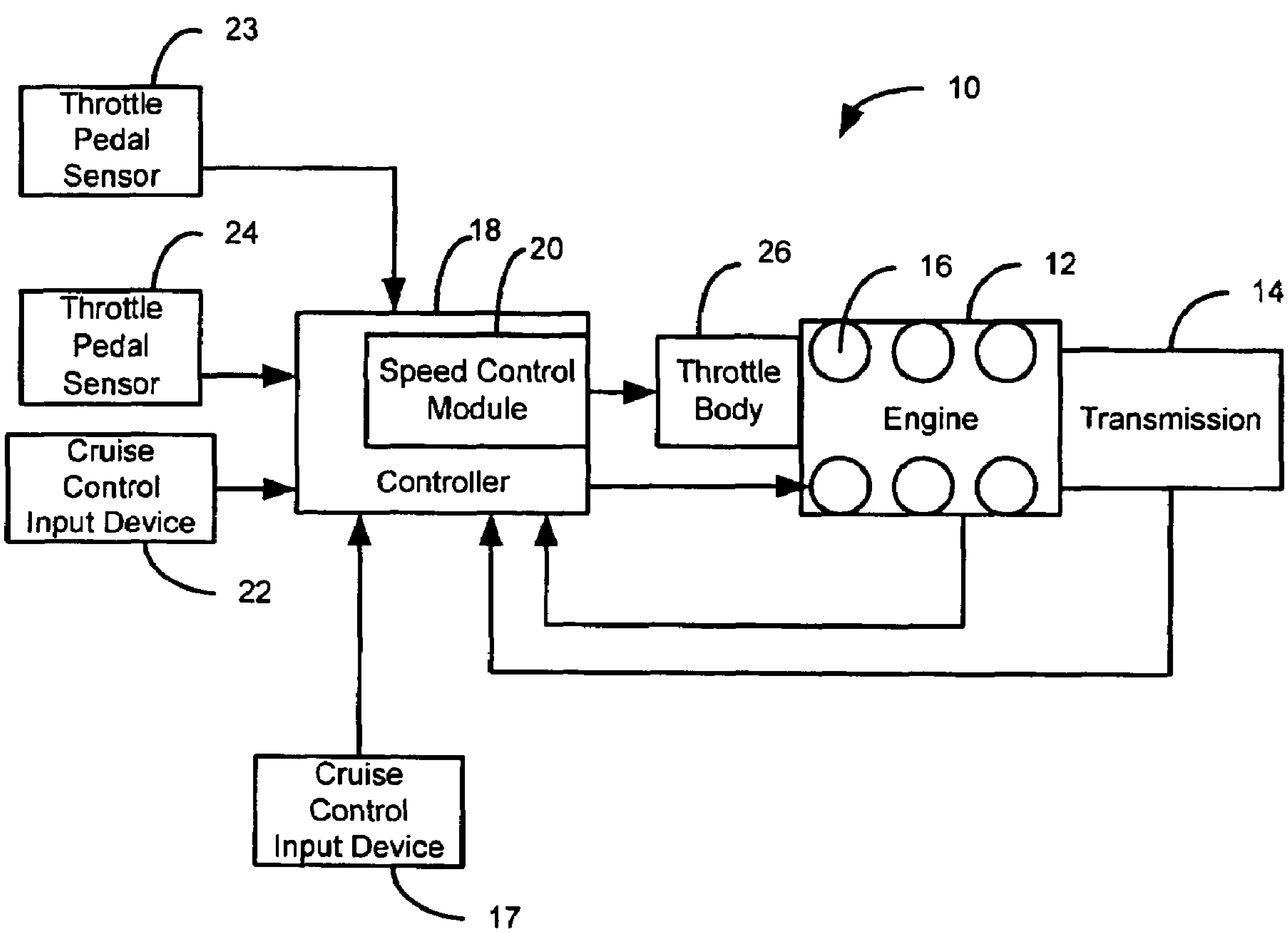
(57) **ABSTRACT**

A method for controlling the speed in a vehicle includes adjusting at least one gain parameter based on a vehicle speed error and the displacement on demand mode of the engine. A new cruise throttle area is calculated from the adjusted gain parameter.

20 Claims, 4 Drawing Sheets



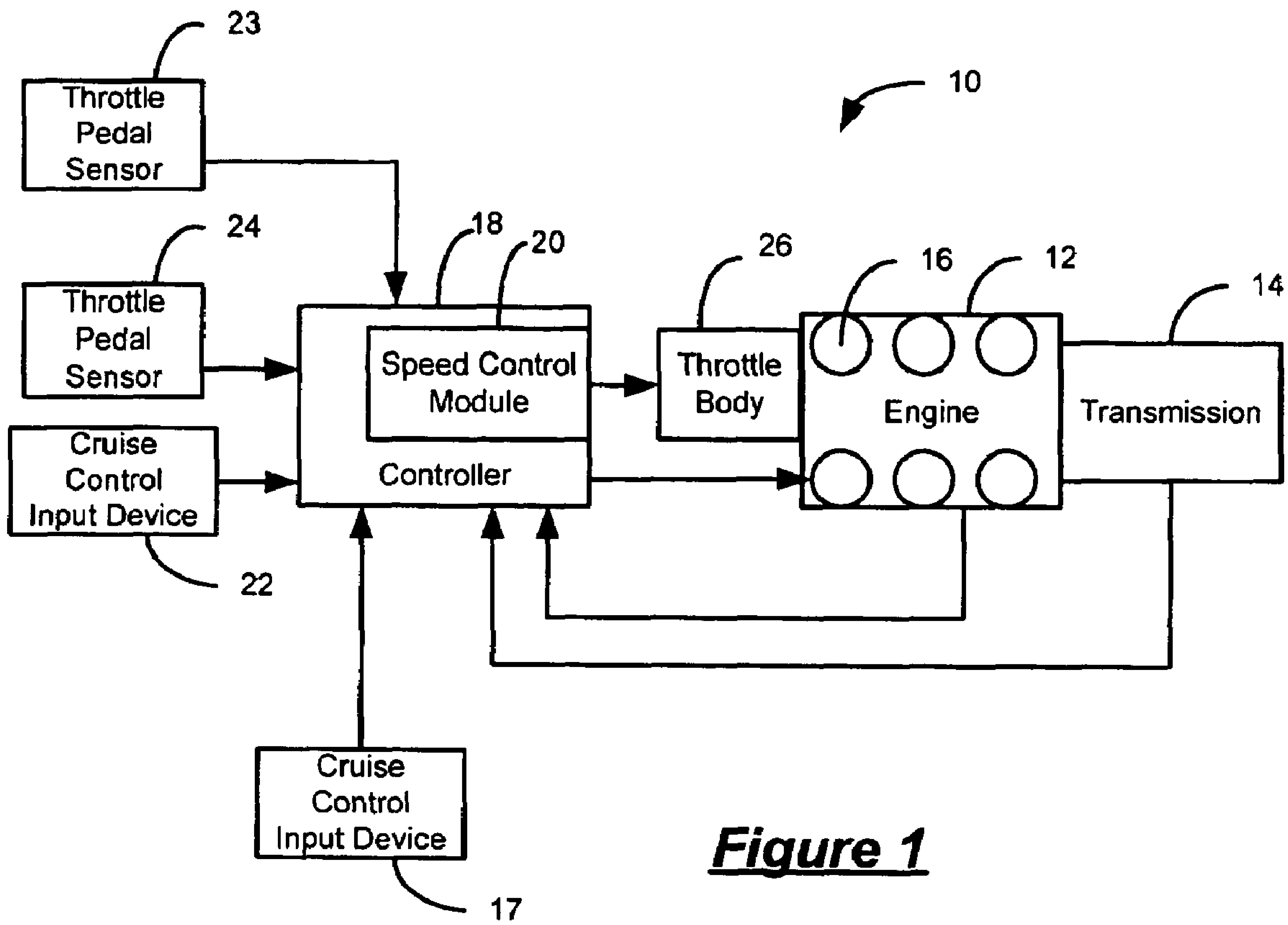

23
Throttle Pedal Sensor
10
24
Throttle Pedal Sensor
18
20
26
16
12
14
Speed Control Module
Throttle Body
Engine
Transmission
Cruise Control Input Device
Controller
22
Cruise Control Input Device
17

Figure 1

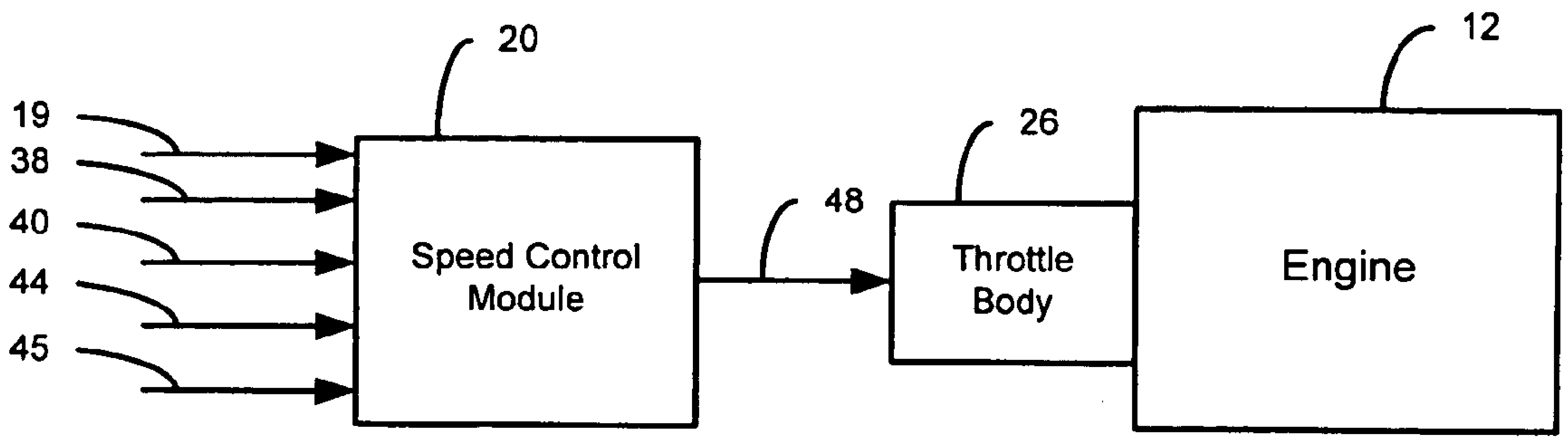


Figure 2

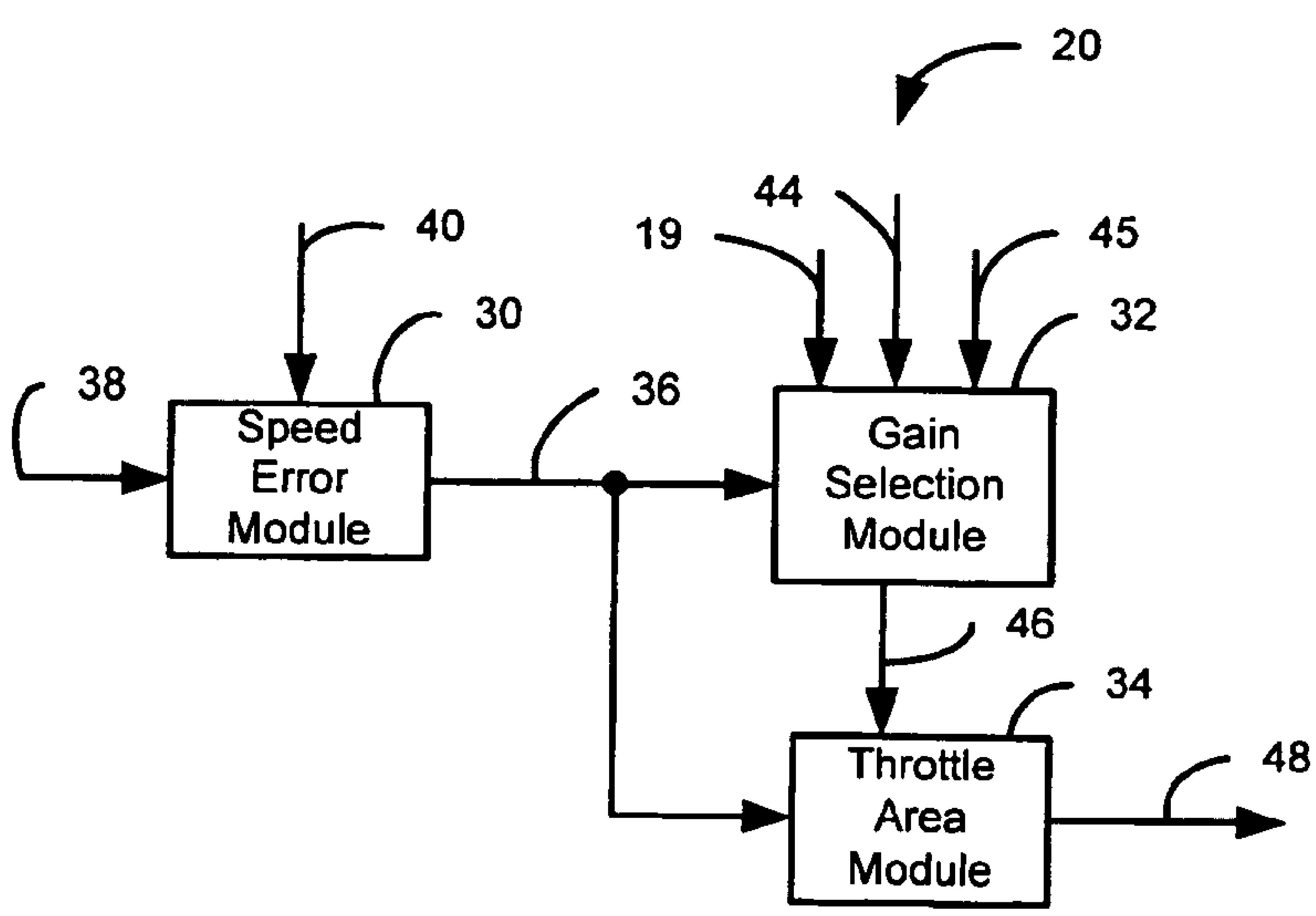


Figure 3

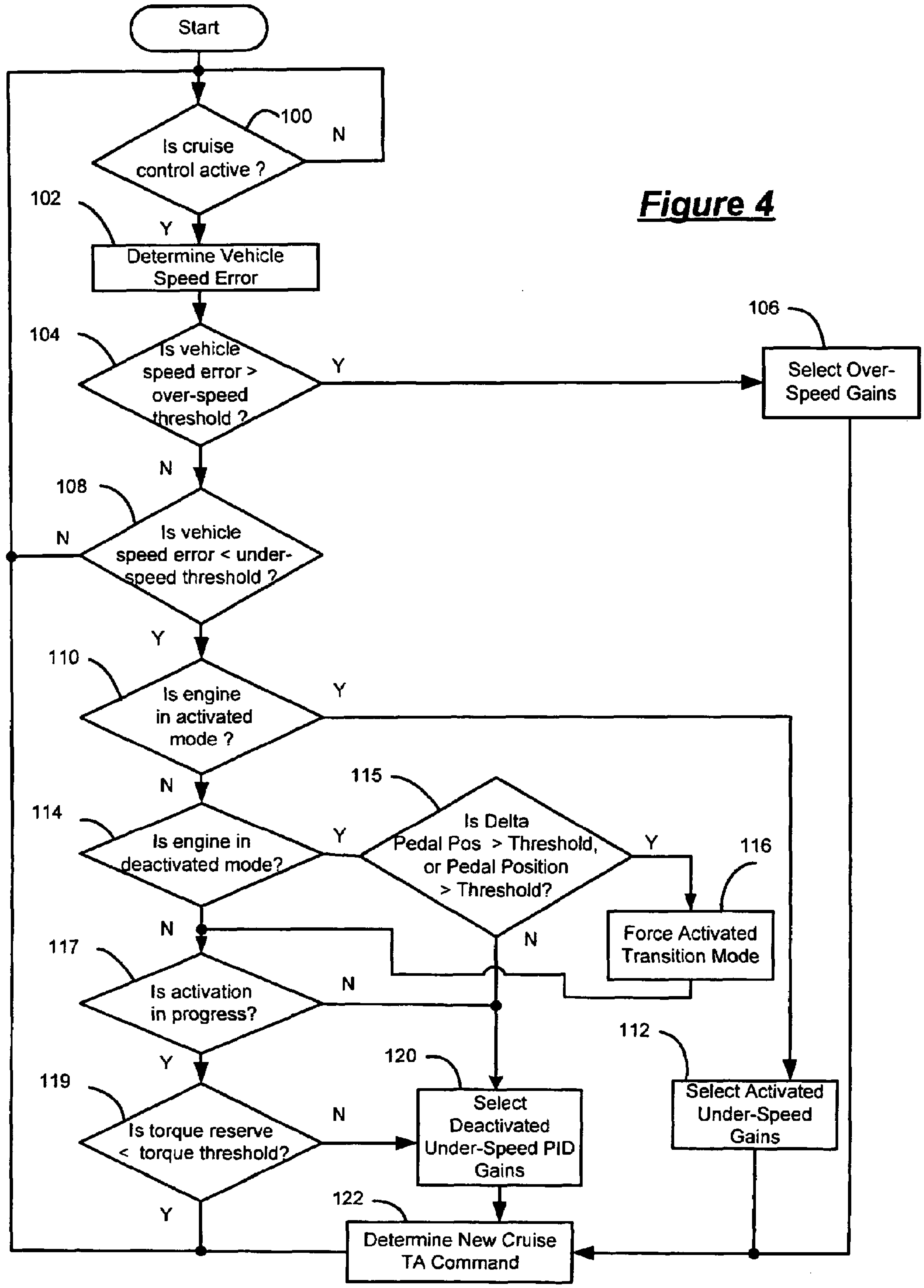

Start
Is cruise control active ?
100
N
Y
102
Determine Vehicle Speed Error
104
Is vehicle speed error > over-speed threshold ?
Y
106
Select Over-Speed Gains
N
108
Is vehicle speed error < under-speed threshold ?
N
Y
110
Is engine in activated mode ?
Y
N
114
Is engine in deactivated mode?
Y
115
Is Delta Pedal Pos > Threshold, or Pedal Position > Threshold?
Y
116
Force Activated Transition Mode
N
N
117
Is activation in progress?
N
Y
112
Select Activated Under-Speed Gains
120
Select Deactivated Under-Speed PID Gains
119
Is torque reserve < torque threshold?
N
Y
122
Determine New Cruise TA Command

Figure 4

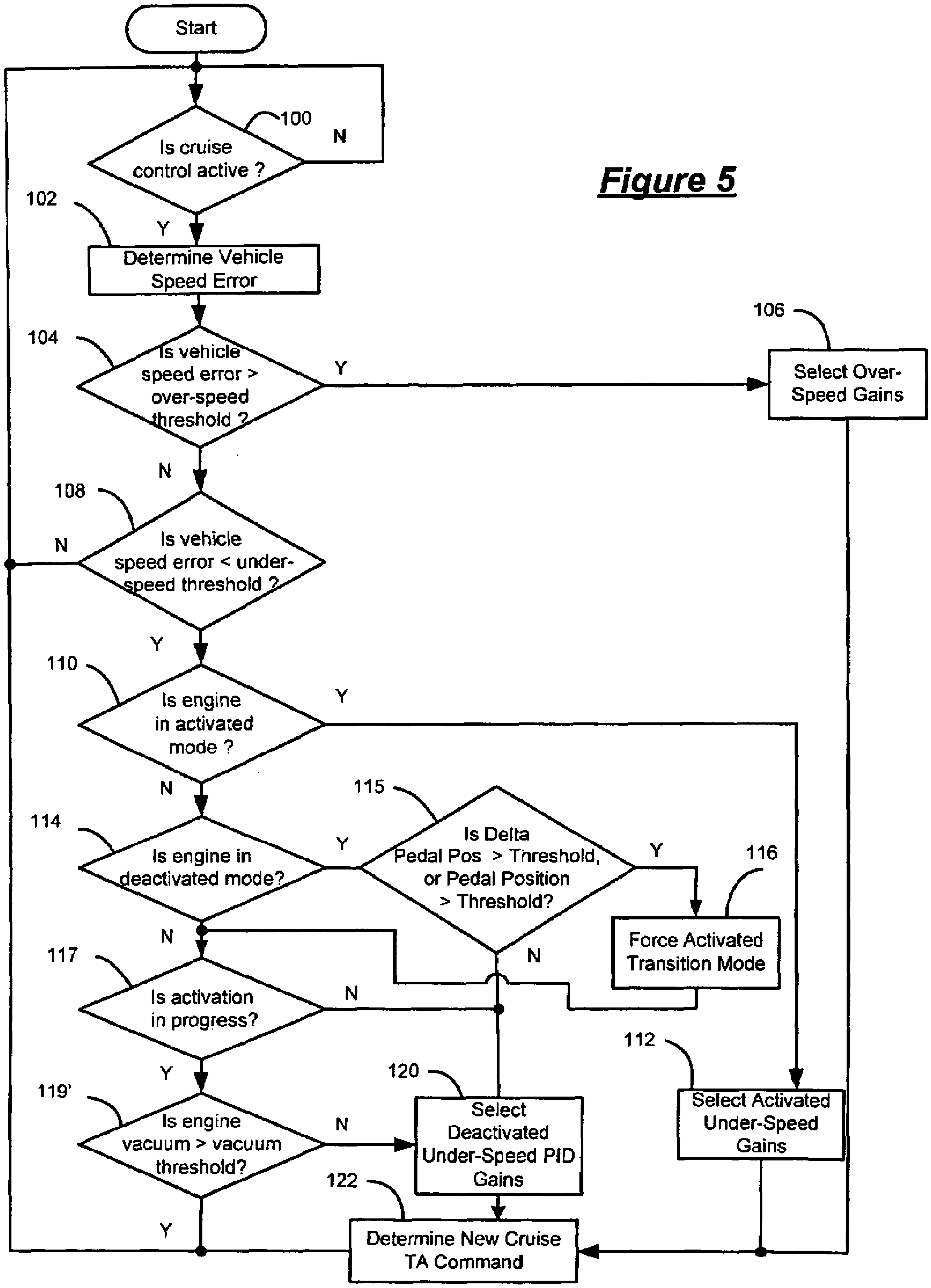

Start
Is cruise control active ?
100
N
102
Y
Determine Vehicle Speed Error
104
Is vehicle speed error > over-speed threshold ?
Y
106
Select Over-Speed Gains
N
108
Is vehicle speed error < under-speed threshold ?
N
Y
110
Is engine in activated mode ?
Y
N
114
Is engine in deactivated mode?
Y
115
Is Delta Pedal Pos > Threshold, or Pedal Position > Threshold?
Y
116
Force Activated Transition Mode
N
N
117
Is activation in progress?
N
Y
112
Select Activated Under-Speed Gains
119'
Is engine vacuum > vacuum threshold?
N
120
Select Deactivated Under-Speed PID Gains
122
Determine New Cruise TA Command
Y

Figure 5

METHOD FOR IMPROVING FUEL ECONOMY AND PERFORMANCE WHEN DEACTIVATING CYLINDERS WITH VEHICLE CRUISE CONTROL

FIELD OF THE INVENTION

The present invention relates to engine control systems for vehicles, and more particularly to a cruise control system for a displacement on demand (DOD) internal combustion engine.

BACKGROUND OF THE INVENTION

Cruise control systems are used to control vehicle speed and vehicle acceleration. When the cruise control system is active, a driver-selected speed is maintained without requiring the driver to operate the accelerator pedal. The cruise control system is manually activated and controlled by the driver via a cruise control input device. The cruise control system may be deactivated by the cruise control input device, application of a brake pedal and/or application of clutch pedal in vehicles with a manual transmission.

The cruise control system adjusts throttle area to control the speed of the vehicle. With electronic throttle control (ETC), an ETC module implements an ETC algorithm that adjusts the throttle area based on sensors, driver commands and/or cruise control algorithm commands.

The throttle valve controls the torque and speed of the engine by metering the supply of air to the engine. An engine controller modulates fuel based on an estimated airflow entering the engine. Sensors monitor the air flow to the engine and the amount of oxygen in the exhaust. The engine controller typically adjusts fuel delivery so that the air-to-fuel ratio is substantially equal to a stoichiometric value.

Some internal combustion engines (ICEs) include engine control systems that selectively deactivate cylinders under low load situations. For example, an eight-cylinder engine can be operated using four cylinders to improve fuel economy by reducing pumping losses. This process is generally referred to as displacement on demand (DOD). As used herein, activated mode refers to operation using all of the engine cylinders. Deactivated mode refers to operation using less than all of the cylinders of the engine (one or more cylinders not active). When cruise control is active and the engine is operating with minimal reserve torque in the deactivated mode, the DOD engine may frequently transition between the activated and deactivated modes based on changing road load conditions, which may cause perceptible torque disturbances and reduced fuel economy.

SUMMARY OF THE INVENTION

A speed control system and method according to the present invention for a vehicle includes a cruise control system and a displacement on demand (DOD) engine with DOD modes. A speed error module calculates a vehicle speed error. A gain selection module selects at least one gain value for at least one correction term of the cruise control system based on the vehicle speed error and the DOD mode of the engine. A throttle area module calculates a new throttle area based on a current throttle position that is adjusted by the at least one correction term.

In other features, the vehicle speed error is based on a difference between a desired speed setpoint and a vehicle speed. The DOD modes include an activated mode, a deactivated mode, an activation transition mode and a deactivation transition mode. The correction term includes at least one of a proportional term, an integral term and a derivative term. A plurality of the correction terms are used and wherein each of the plurality of correction terms includes a gain.

In yet other features, the gain selection module sets the gains of each of the correction terms to baseline over-speed values when the vehicle speed error is greater than an over-speed threshold value. The gain selection module reduces the gains of the correction terms to lower gain values when the vehicle speed error is less than an under-speed threshold value, the DOD engine is in the deactivated mode, and engine activation transition is not in process. The gain selection module at least one of generates and receives a reserved torque value and a torque threshold value. The gain selection module reduces the gains of the correction terms to lower gain values when the vehicle speed error is less than an under-speed threshold value, the DOD engine is in an activation transition mode, and the reserved torque value is not less than a torque threshold value. The gain selection module sets the gains to the baseline under-speed values when the vehicle is under-speed by less than an under-speed threshold value and the DOD engine is in the activated mode.

Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1** is a functional block diagram of a vehicle with a displacement on demand engine and a controller including a speed control system;

FIG. **2** is a functional block diagram of the speed control system including the speed control module;

FIG. **3** is a more detailed functional block diagram of the speed control module of FIG. **2**;

FIG. **4** is a flow chart illustrating steps performed by the speed control module; and

FIG. **5** is a flow chart illustrating steps performed by the speed control module in an alternate implementation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. As used herein, the term module refers to an application specific integrated circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that execute one or more software or firmware programs, a combinational logic circuit, or any other suitable components that provide the described functionality. For purposes of clarity, the same reference numbers will be used in the drawings to identify similar elements.

The present invention minimizes cylinder deactivations and improves fuel economy while controlling the speed of a vehicle when cruise control is active. At least one gain value for at least one correction term of a closed-loop speed control system is based on a vehicle speed differential and a displacement on demand mode of the engine. The vehicle speed differential is the commanded speed subtracted from the measured speed. A new throttle area is calculated based on the current throttle position and adjusted by the correction terms.

The correction term may include at least one of a proportional, integral or derivative term. Each correction term has it's own gain, which are set to baseline over-speed levels when the vehicle speed differential is greater than an over-speed threshold value.

The gains are reduced to lower values when one of the following two sets of criteria are met. The gains can be reduced to a lower value when the vehicle speed differential is less than an under-speed threshold value, the DOD engine is in the deactivated mode, and engine activation transition is not in process. The gains can also be reduced to lower values when the vehicle is under-speed, the DOD engine is in the activation transition mode, and a reserved torque value is not less than a torque threshold value. The gains are set to the baseline under-speed values when the vehicle is under-speed by less than an under-speed threshold value and the DOD engine is in the activated mode.

A new cruise control throttle area is not calculated when the vehicle speed is within a predetermined range from the desired speed set point. A new throttle area is also not calculated when the vehicle speed differential is less than an under-speed threshold, the DOD engine is in the activation transition mode and a reserved torque value is less than a torque threshold value.

Referring now to FIG. **1**, a vehicle **10** includes an engine **12** that drives a transmission **14**. The engine **12** includes N cylinders **16** that are selectively deactivated during engine operation. Although FIG. **1** depicts six cylinders (N=6) in a "V" arrangement, it can be appreciated that the engine **12** may include additional or fewer cylinders **16** and/or have an in-line configuration. For example, engines having 4, 5, 6, 8, 10, 12 and 16 cylinders are contemplated.

A controller **18** communicates with one or more engine operating sensors and/or environmental sensors, which are generally designated **17**. The sensors may include oxygen sensors, mass air flow sensors, temperature sensors, engine and/or transmission speed sensors and the like. Other sensed parameters may be derived using models. During periods of light engine load, the controller **18** selectively deactivates one or more cylinders **16**. In an exemplary embodiment, N/2 cylinders are deactivated. Upon deactivation of the cylinders **16**, the controller **18** increases the torque output of the remaining cylinders **16** to maintain the desired engine power.

Referring now to FIG. **2**, during operation, the controller **18** selects a DOD operating mode of the engine and sends a mode signal **19** to the speed control module **20**. The DOD operating modes include four modes: a deactivated mode with one or more of the cylinders **16** not operating; an activated mode with all of the cylinders **16** operating; a deactivation transition mode during which the engine **12** is transitioning from the activated mode to the deactivated mode; and an activation transition mode during which the engine **12** is transitioning from the deactivated mode to the activated mode. The controller **18** selects one of the four DOD modes, depending upon the operating conditions.

The speed control module **20** controls the speed and acceleration of the vehicle **10** when activated. The inputs to the speed control module **20** include, but are not limited to, inputs from the engine **12**, the transmission **14**, cruise control user inputs **22**, a brake pedal sensor **23**, and a throttle pedal position sensor **24**. The inputs to the module **20** are used to control the throttle area in the throttle body **26**.

Referring now to FIGS. **3**, **4**, and **5**, the speed control module **20** includes a speed error module **30**, a gain selection module **32** and a throttle area module **34**. The speed error module **30** calculates a speed error **36** as shown in step **102** by calculating the difference between a measured vehicle speed **38** and a desired speed set point **40**. The measured vehicle speed **38** can be measured and/or estimated from transmission output speed, estimated wheel speed or using any other suitable approach. The desired speed set point **40** is selected by the driver using the cruise control user inputs **22**.

The gain selection module **32** determines the proper gains to be applied when the vehicle **10** is not operating within a predetermined range of the desired speed set point **40**. Typically, higher gains reduce system response times. In other words, the cruise control system returns to the driver-selected speed set point **40** more quickly. The higher gains, however, also increase the probability of overshoot and instability. Conversely, lower gains increase system response times and do not respond as quickly and reduce overshoot and instability.

If the cruise control is not active in step **100**, control flows back to step **100**. If the cruise control is active in step **100**, the speed error is determined in step **102**. The gain selection module **32** compares the speed error **36** to an over-speed threshold and an under-speed threshold. If the speed error **36** is greater than an over-speed threshold value in step **104**, over-speed proportional, integral and derivative (PID) gains are selected in step **106** and the new cruise throttle area **34** is determined in step **122**. High over-speed PID gains can be used to quickly slow the vehicle **10** down without causing a DOD activation transition event because engine torque is being reduced.

In step **104**, if the speed error **36** is not greater than the over-speed threshold value, control continues to step **108**. In step **108**, if the speed error **36** is not less than the under-speed threshold value, control returns to step **100**. Otherwise, if the speed error **36** is less than the under-speed threshold value in step **108**, flow continues with step **110** where the DOD mode **19** of the engine **12** is considered.

If the engine **12** is in the activated mode in step **110**, the activated under-speed PID gains are selected in step **112** and control continues with step **122**. If the engine is not in activated mode in step **110**, control continues with step **114**. If the engine **12** is in the deactivated mode in step **114**, accelerator pedal position and delta accelerator pedal thresholds are evaluated in step **115** to determine whether the driver intends to accelerate past the desired speed set point **40**. If the delta accelerator pedal position is not greater than the delta accelerator pedal threshold and the accelerator pedal position is not greater than the accelerator pedal position threshold in step **115**, the driver does not intend to accelerate and the deactivated under-speed PID gains are selected in step **120**. The deactivated under-speed PID gains are lower than the baseline activated under-speed gains. Control continues from step **120** to step **122** and then back to **100**.

Lower deactivated under-speed PID gains allow vehicle speed correction while reducing undesired activation transitions caused by the torque request overshooting the maximum available deactivated mode torque when vehicle speed errors are small. If a delta accelerator pedal position **44** is greater than the delta accelerator pedal threshold or the accelerator pedal position **44** is greater than the throttle pedal position threshold in step **115**, the activation mode is commanded in step **116**. Control continues from step **116** to step **117**. Forcing the activation transition mode based on accelerator pedal position changes reduces situations where the deactivated engine torque reserve is exhausted, which causes torque disturbances during the delay of the activation transition. If the engine **12** is not in deactivated mode in step **114**, control continues with step **117**.

In FIG. **4**, if the engine **12** is in the activation transition mode in step **117**, and a torque reserve value **45** is not less than a torque threshold in step **119**, lower deactivated under-speed PID gains are selected in step **120**. If the torque reserve is less than the torque threshold in step **119**, deactivated engine torque reserve is exhausted, control bypasses step **122** and control returns to step **100**. Alternatively and as shown in FIG. **5**, if the engine **12** is in the activation transition mode in step **117**, control continues with step **119'**. If an engine vacuum value **45** is not less than an engine vacuum threshold in step **119'**, lower deactivated under-speed PID gains are used in step **120**. If the engine vacuum value **45** is less than the engine vacuum threshold in step **119'**, control bypasses step **122** and control returns to step **100**.

In both FIGS. **4** and **5**, if the engine **12** is in not in the activation transition mode, by default, the engine **12** is in the deactivation transition mode. In this case, lower deactivated under-speed PID gains are used in step **120**. Therefore, if the engine **12** is not in the activation transition mode in step **117**, control continues with step **120**.

In step **122**, the PID gains selected in steps **106**, **112**, or **120** are used to determine the new cruise throttle area command. The throttle area module **34** uses the PID gains **46** determined by the gain selection module **32** to calculate the new cruise throttle area command **48**. The throttle area module **34** calculates the new cruise throttle area using a PID or other similar calculation based on the gain values **46** and the determined speed error **36**. There are some exceptions to determining the new cruise throttle area command. If the vehicle speed error **36** is less than an over-speed threshold and is greater than the under-speed threshold, the vehicle speed **38** is within a predetermined range of the desired speed set point **40**. The cruise throttle area command **48** remains unchanged.

Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the present invention can be implemented in a variety of forms. Therefore, while this invention has been described in connection with particular examples thereof, the true scope of the invention should not be so limited since other modifications will become apparent to the skilled practitioner upon a study of the drawings, specification, and the following claims.

What is claimed is:

1. A method for controlling the speed of a vehicle including a cruise control system and a displacement on demand (DOD) engine with DOD modes, comprising:

calculating a vehicle speed error;

selecting at least one gain value for a correction term of a said cruise control system based on said vehicle speed error and said DOD mode of said engine; and

generating a new throttle area that is based on a current throttle position and that is adjusted by said correction term; and

controlling a throttle of the vehicle based on the new throttle area to control the speed of the vehicle.

2. The method of claim **1** wherein said vehicle speed error is based on a difference between a desired speed setpoint and a vehicle speed.

3. The method of claim **1** wherein said DOD modes include an activated mode, a deactivated mode, an activation transition mode and a deactivation transition mode.

4. The method of claim **1** wherein said correction term includes at least one of a proportional term, an integral term and a derivative term.

5. The method of claim **1** wherein a plurality of said correction terms are used and wherein each of said plurality of correction terms includes a gain.

6. The method of claim **5** further comprising setting said gains of each of said correction terms to baseline over-speed values when said vehicle speed error is greater than an over-speed threshold value.

7. The method of claim **5** further comprising reducing said gains of said correction terms to lower gain values when said vehicle speed error is less than an under-speed threshold value, said DOD engine is in the deactivated mode, and an engine activation transition is not in process.

8. The method of claim **5** further comprising generating a reserved torque value and a torque threshold value.

9. The method of claim **8** further comprising reducing said gains of said correction terms to lower gain values when said vehicle speed error is less than an under-speed threshold value, said DOD engine is in an activation transition mode, and said reserved torque value is not less than a torque threshold value.

10. The method of claim **6** further comprising setting said gains to said baseline under-speed values when said vehicle is under-speed by less than an under-speed threshold value and said DOD engine is in the activated mode.

11. A speed control system for a vehicle including a cruise control system and a displacement on demand (DOD) engine with DOD modes, comprising:

a speed error module that calculates a vehicle speed error;

a gain selection module that selects at least one gain value for a correction term of said cruise control system based on said vehicle speed error and said DOD mode of said engine; and

a throttle area module that calculates a new throttle area based on a current throttle position that is adjusted by said correction term.

12. The speed control system of claim **11** wherein said vehicle speed error is based on a difference between a desired speed setpoint and a vehicle speed.

13. The speed control system of claim **11** wherein said DOD modes include an activated mode, a deactivated mode, an activation transition mode and a deactivation transition mode.

14. The speed control system of claim **11** wherein said correction term includes at least one of a proportional term, an integral term and a derivative term.

15. The speed control system of claim **11** wherein a plurality of said correction terms are used and wherein each of said plurality of correction terms includes a gain.

16. The speed control system of claim **15** wherein said gain selection module sets said gains of said correction terms to baseline over-speed values when said vehicle speed error is greater than an over-speed threshold value.

17. The speed control system of claim **15** wherein said gain selection module reduces said gains of said correction terms to lower gain values when said vehicle speed error is less than an under-speed threshold value, said DOD engine is in the deactivated mode, and an engine activation transition is not in process.

18. The speed control system of claim **15** wherein said gain selection module at least one of generates and receives a reserved torque value and a torque threshold value.

19. The speed control system of claim **18** wherein said gain selection module reduces said gains of said correction terms to lower gain values when said vehicle speed error is less than an under-speed threshold value, said DOD engine is in an activation transition mode, and said reserved torque value is not less than a torque threshold value.

20. The speed control system of claim **16** wherein said gain selection module sets said gains to said baseline under-speed values when said vehicle is under-speed by less than an under-speed threshold value and said DOD engine is in the activated mode.

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